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A HEAT-INSULATING LIGHTWEIGHT MATERIAL

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A technology for producing lightweight material suitable for service in unprotected linings up to temperatures 1300 – 1350°C is considered. The material has apparent density from 0.35 to 0.70 g/cm^3 and exhibits good heat-insulating and strength parameters.

Lightweight refractories are widely used for thermal insulation along with fibrous materials. To impart heat-insulating properties to such materials, their porous structure has to be optimized. The use of high-quality lightweight parts with apparent density 0.30 – 0.65 g/cm^3 in thermoelectric sets decreases fuel consumption by 20 – 70%. With the specified apparent density of the material, its thermal conductivity also depends on the pore size, the nature and the number of the interparticle contacts, the thermal conductivity of its crystalline and vitreous components, the temperature, etc.

Lightweight materials can be produced using different technologies [1]. Thus, when burning-out additives (sawdust, saccharose, foam polystyrene, etc.) are used, the porosity reaches 70 – 80%, and the pore size reaches 0.1 – 4.0 mm. The ultimate material has a substantial amount of microcracks and weak contacts, which gives it low strength and a low elasticity modulus, increased gas permeability, and high heat resistance.

Foam materials are also produced by chemical swelling (e.g., using aluminum powder and calcium oxide hydrate or phosphoric acid), by using phosphate binders in combination with foaming agents; by impregnation of organic foams with ceramic suspensions, etc.

The study in [2] shows the expediency of producing lightweight materials using foam plastics technology (USSR Author's Certificate 130829). The lightweight material was produced by mixing a finely pulverized refractory material with glycerin adipate; then toluylene diisocyanate was added as the foaming agent and the mixture stirred. In the course of the exothermic reaction, the volume becomes 10 times higher and the ester is polymerized, which makes it possible to accelerate the drying of the raw product (its strength reaches 6.5 MPa with a density of 0.6 g/cm^3). The most convenient plastifier (a composition based on Al_2O_3) was found to be a mixture of triethylene glycol and tricresyl phosphate. Its use allowed for an increase in the amount of the refractory filler in the batch up to 70 – 80% and a decrease in the fired product density to 0.35 – 050 g/cm. The drawbacks of this technology consist in the high cost of the ancillary materials and the presence of cyanates in them.

Foam ceramics methods are in wide use in industry: swelling ceramic slip by introducing a pore-forming agent, or mixing the slip with ready-made foam [1]. The cellular structure resulting from the mixture of slip and foam is fixed in the course of drying and firing. The materials used for foam formation are saponin, gelatin, albumin, casein, colophony soap with joiner's glue, and others. The technology is fairly simple and stable in production. Its main difficulty consists in the need for high-quality drying of the semi-finished product (from a moisture content of 45 – 60% to about 1%).

The Ukrainian Research Institute for Porcelain and Faience Industry has developed a number of compositions for production of lightweight materials using the foam-ceramic method (USSR Author's Certificate 1759821). Thus, with respect to the production of lightweight heat-insulating material with increased compressive strength and heat resistance, it was suggested to add finely pulverized porcelain scrap to the refractory component of the material (kaolin, alumina, and perlite sand). Furthermore, the Aragatskii perlite was replaced by perlite from Ukrainian mineral deposits. As a result, a low apparent density was achieved and the strength of the material was improved.

The mixture for casting (with the consistency of thick cream) was prepared in a propeller mixer. The foam-forming agent based on the glue-colophony paste was made in a horizontal mixer with a rotational speed of 100 – 1500 min^{-1}. After that, the porous slip was prepared, and the foam mixture was produced on its basis. The articles were cast in

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TABLE 1

Batch composition	Maximum size of perlite grains, mm	Perlite part by volume in the batch, %	Properties of products after firing at temperatures of 1400 – 1420°C*			
			apparent density, g/cm^3	compressive strength, MPa	volume shrinkage, %	thermal conductivity, W/(M · K)
1	3	60	0.60 (0.6)	8.5 (4.3)	10	0.25 (0.25)
2	3	80	0.35 (0.4)	1.6 (1.0)	14	0.20 (0.20)
3	2	65	0.52	3.4	12	0.23
4	2	60	0.58 (0.6)	8.9 (4.3)	11	0.23 (0.25)
5	1	65	0.48	2.9	13	0.20
6	5	65	0.50	3.2	13	0.32

* Parameters of the products manufactured at the Snegirevskii Refractory Works are indicated in brackets.

metal molds placed on trays and dried and fired at temperatures 1380 – 1420°C. The advantages of the developed method include virtually complete suppression of syneresis in molding (the foam substance on casting does not sag inside the molds)

The available vitreous phase contained in the porcelain scrap facilitates the dissolution of silicon dioxide and free aluminum oxide. This accelerates the mullite-forming reaction with subsequent crystallization of mullite on the pore walls and reinforcement of the pores. Due to the increased strength of the porous macrostructure of the material, the mechanical strength of the product is improved. Moreover, the reinforcement of the pore walls impedes the propagation of cracks and increases the material heat resistance.

Increase in the kaolin content in the mixture composition, which improves the strength of the product, is limited by increasing shrinkage of the material, leading to product deformation.

Analysis of the properties of articles made with an introduction of various quantities of swelled perlite of different fractions to the batch indicated that as the perlite content in the batch increases, the apparent density of the articles decreases. At the same time, the compressive strength decreases, since the bridges between the pores become thinner.

A variation in the average size of perlite grains (provided its volume content remains the same) has an insignificant effect on the apparent density of the product (Table 1). It can be seen that the strength of the finished products is almost twice as high as the standard strength of the material with equal density, for instance, the material manufactured at the Snegirevskii Refractory Works.

The thermal conductivity is largely determined by the perlite grain size. With the single-fraction perlite composition, the thermal conductivity of the products decreases, as their apparent density is reduced. In the articles with equal apparent density, the thermal conductivity decreases with decrease in the perlite grain size.

The highest thermal conductivity is exhibited by articles made on the basis of the coarse perlite fractions. At low temperatures, the large pores in these articles increase the convective component of the heat transfer. At high temperatures, the increased size of the pores results in an additional decrease in the scattering coefficient and the heat radiation absorption coefficient, i.e., it leads to increased radiant heat transfer. Both factors decrease the heat-insulating efficiency.

The obtained material is suitable for service in unprotected linings (similar to the furnaces produced by the Ridhammer and the Naber companies) up to temperatures 1300 – 1350°C.

Thus, on introducing the optimum quantity of finely pulverized porcelain scrap and swelled perlite of different fractions, it is possible to produce lightweight articles with apparent density from 0.35 to 0.70 g/cm^3 and good heat-insulating and strength parameters.

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